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Abstract

Many socio-political sites have emerged where science and politics interact. In this article we explore how climate change science is connected to climate change governance. When formally institutionalised, as in IPCC or UNFCCC, these sites may be referred to as *boundary organisations*. These institutions engage in the quality assessment of scientific research, but also the design of innovative policy instruments, or evaluation of policy impacts – activities that we refer to as *boundary work*. Boundary work is inherently 'tricky business'. Science and politics are normally demarcated spheres with different sacred stories. Scientists aspire to 'speak truth to power', while policymakers want 'politics on top and science on tap'. Boundary work endeavours to coordinate these apparently incompatible aspirations. In this article we describe, analyse and assess whether, to what extent, and how the major international and some national boundary organisations in climate change governance have been able to avoid over-politicisation and over-scientization. We demonstrate that the nature and success of boundary organisations and the ways they work depend on: (1) the degree to which the climate change problem is defined as 'wicked' or unstructured, or as (relatively) 'tame' and structured; (2) the stage of the policy process; and (3) characteristics of the policy network and the socio-political context: the degree to which relevant players insist on strict separation and a linear relation from science to politics, or, alternatively, are tolerant of a blurring of the boundaries and hence a two-way, co-productive relation between science and politics.

Like many environmental problems, climate change became perceptible only through increasing scientific knowledge. Scientific knowledge compiled by the Intergovernmental Panel on Climate Change (IPCC) has been at the heart of attempts to build a global policy regime centred on the UN Framework Convention on Climate Change (UNFCCC) and especially its Kyoto protocol.[1] The IPCC is a prominent example of a boundary organisation. These are 'institutions that straddle the shifting divide between politics and science'.[2] Until recently, the IPCC commanded such respect that it was awarded the Nobel Peace prize in 2007. However, in 2009 this esteem was shaken as a result of the events that became known as 'climategate': the disclosure of a number of emails between climate prominent scientists that appeared to show scientists manipulating data about climate change and attempting to suppress dissenting scientific papers. Although no misconduct was eventually found, these events, along with the discovery of some minor errors in the 4th IPCC assessment report,[3,4] tarnished the public trust in climate scientists and the IPCC, fuelled climate scepticism, and arguably contributed to deadlock in the negotiations of the 2009 Conference of Parties (COP15) in Copenhagen. A better understanding of the science-policy interface is crucial to understanding the history of the changing status of climate change science, and the current challenges facing climate change policy making.

This review of what we know about the science-politics interface in climate change governance starts from the premise that productive interaction requires so-called boundary work[5] to coordinate and at the same time separate the worlds of science and policy/politics. We describe how boundary work in international and national climate change governance is organised in boundary arrangements or organisations. These organisations are embedded in and shaped by contexts of policy issue politics and political-cultural spheres.[6,7] We discuss how the characteristics of boundary work and boundary arrangements in the international climate policy regime and its interactions with national regimes help understand why UNFCCC implementation is stalling. We conclude with a cautious discussion of directions for improved boundary work. How this can be embedded in new or existing boundary arrangements is context-dependent, as both theory and our empirical material demonstrate.

BOUNDARY WORK: A MULTILEVEL HEURISTIC FRAMEWORK

The relationship between science and politics is often conceptualised as a linear process of knowledge transfer, research use or impact.[8,9,10] Policymakers and politicians like to suggest that they are 'on top' and call on the services of scientists who are 'on tap'. Scientists see their role as neutral, objective and independent experts, speaking 'truth to power'. However, both these 'sacred' or front-office narratives of idealised worlds neglect the more 'profane' or back-office truth that the production of policy advice cannot realistically be described in terms of clear boundaries between science and politics; the zones of engagement and transgression are inevitably fluid and vague. From a macro-perspective, science-policy interactions are on-going co-productions[11] between the scientization of politics and the politicisation of science.[12] At meso- and micro-level there is not a complete blurring of boundaries. Given the need for participation from different institutional spheres in the production of policy advice, a division of work is required.

Boundary work can then be understood as the attempts to define practices in contrast to each other through *demarcation*, as well as attempts to find productive *coordination* through a division of labour.[5,13] In the International Panel on Climate Change (IPCC), experts and policy makers literally work together: in such conditions boundary work always happens, whether intentionally or not. Concern for high-quality performance makes expert advisors and policymakers mutually dependent; yet, they have to guard their separate identities and formal independence. Demarcation and coordination are two sides of the same coin. Boundary work is full of paradoxes and dilemmas: the relationship may look stable, but will always remain contested. Boundary work occurs in all science-policy interactions at different levels (Figure 1)[6,7] and to present a comprehensive picture therefore

means to understand multilevel science-policy interactions and the ways these levels interact. The multilevel heuristic framework presented below draws together insights from older work on science-politics interactions and more recent research perspectives. [2,5,14,15,16] We will now describe each of these levels, including insights that will help understand boundary work in climate change governance at each level.

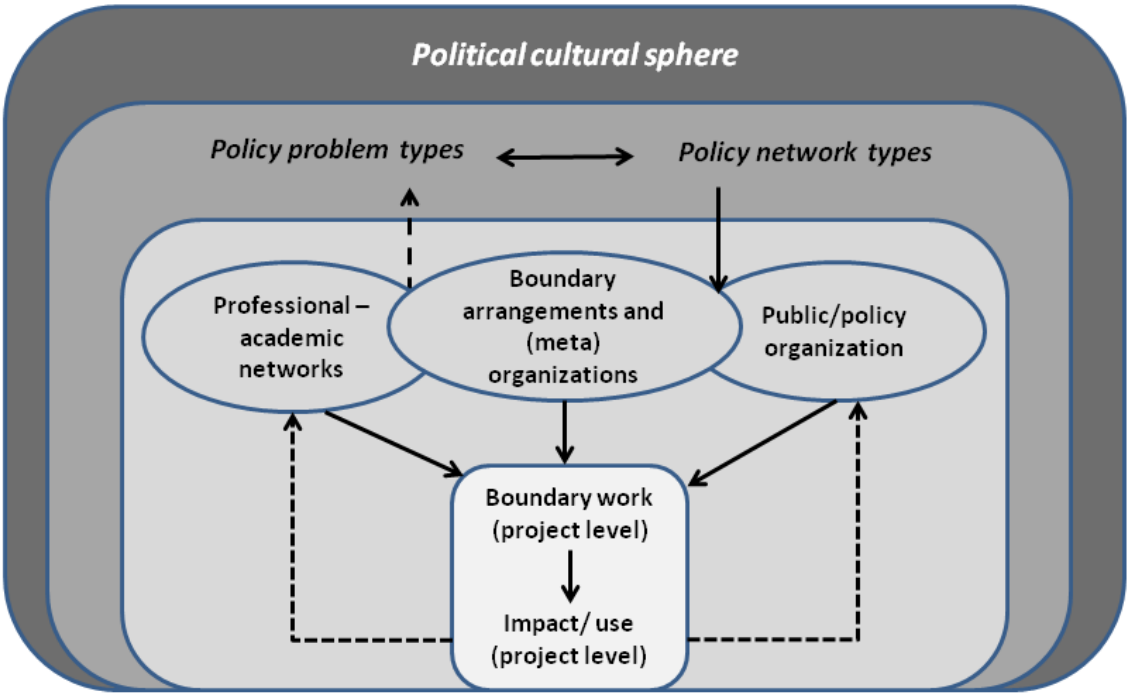

Figure 1. Multi-level conceptual framework for understanding science-policy interactions

Boundary work in projects

At the micro-level, policy advice *projects* reveal practices where the boundary is at its most fuzzy and sometimes 'up for grabs', as it has to be negotiated and renegotiated in the smallest details; for example when the Statement for Policymakers and the Synthesis Reports are produced by the IPCC Working Groups. Important aspects of boundary work in projects are unwritten rules, habits and expectations for dealing with uncertainty, with conflicting knowledge, and with different knowledge types. New participants or a new context, for example the post-'climategate' scrutiny by the InterAcademy Council, mean that these rules have to be re-negotiated.

The quality of boundary work projects for policymakers (indicated by the dotted upward feedback loops) can be evaluated by the degree to which criteria of *credibility* (technically adequate in handling of evidence), *legitimacy* (fair, unbiased, respectful of all stakeholders) and *salience* (relevant to the decision or policy) are simultaneously achieved for relevant stakeholders to the extent possible.[17,18] Students of knowledge utilisation distinguish between three types of policy relevance: instrumental (science delivers data and establishes causalities), conceptual (science delivers new ideas), and symbolic (science legitimizes decisions already taken).[10,19] For scientists, projects represent monetary and symbolic resources for specific research programmes or, more broadly, epistemic debates on promising new (inter)disciplines, paradigms, or long-term research lines (also indicated by upward feedback loops).

Boundary organisations

Boundary organisations are the formalised manifestation of the more general phenomenon of boundary arrangements.[2,20] Boundary arrangements include a wide variety of hybrid organisational forms that straddle and mediate the boundary between professional-academic networks and public sector or policy organisations, of which formal boundary organisations are one type.[21] Boundary organisations typically display several features. Not all of these occur in each organisation, and each may be present in stronger or weaker form[15,18]:

Double participation: people from both the policy/politics and the scientific world are represented and participate in the activities of the boundary organisation or arrangement, as well as professionals who serve a mediating role. For example, in the IPCC government-appointed scientists, diplomats representing national governments, NGOs and business representatives interact in varying configurations.[22,23]

Dual accountability: the leadership or management is simultaneously accountable to representatives of both science and politics. For example, the European Environment Agency has a Management Board to deal with political issues like salience and legitimacy, and a Scientific Board to attend to issues of scientific credibility.[24] Dual accountability leads to a split between sacred or front-office narratives of boundary work for official use in external accountability relations, e.g. to members of parliament and the press, and profane or back-office 'insider' narratives in internal accountability relations, e.g. between experts of different advisory bodies and departmental policy makers.[25,26,27] This 'double-speak' is reflected in the scientific accounts of the science-policy interface: linear transfer being the sacred story, and boundary work for productive co-production as the profane account. Paradoxically, in order to enable boundary work as productive interaction, it is in the institutional self-interest of both science and politics to *co-produce* the linear knowledge transfer story as official legitimation of their relationship.

Use of boundary objects: boundary organisations provide the opportunity and sometimes the incentives for the creation and use of boundary objects and standardized packages that generate a 'symbolic world' in which both scientists and policymakers may coordinate their activities.[28,29] Examples are indicator systems, econometric or climate models, report series, etc. In IPCC, key texts like the Statement for Policymakers and the Synthesis Reports, but also methods of calculating anthropogenic carbon dioxide emissions are typical examples of boundary objects since they are the result of procedural and substantive intertwinement of scientific and political considerations.[22,23]

Policy issue politics

Boundary organisations are part of larger policy networks. Such networks have *policy issue politics*, i.e. the combination of cognitive processes ('puzzling') and competitive interaction ('powering') that is characteristic for policymaking in a particular domain.[30] Policy issue politics usually follow the logic of the type of policy problem and the stage of the policymaking process.

Problem types constrain which problem solving strategy and policymaking style is appropriate.[30] In the case of *structured problems* (strong value consensus and knowledge certainty) a central-rational rule approach to governance permits 'outsourcing' problem solving to bureaucratic or scientific/professional, closed epistemic communities.[31] In the case of *unstructured or 'wicked' problems* (high value dissent and lasting deep uncertainties) an agonistic and polarised governance style will come about, allowing numerous and different types of stakeholders to play a role, sometimes with flexible boundary arrangements as spaces for open deliberation and learning. Intermediate problem types of moderately structured problems (goals or means) give rise to pragmatic, overlapping professional and advocacy networks and arrangements.[30]

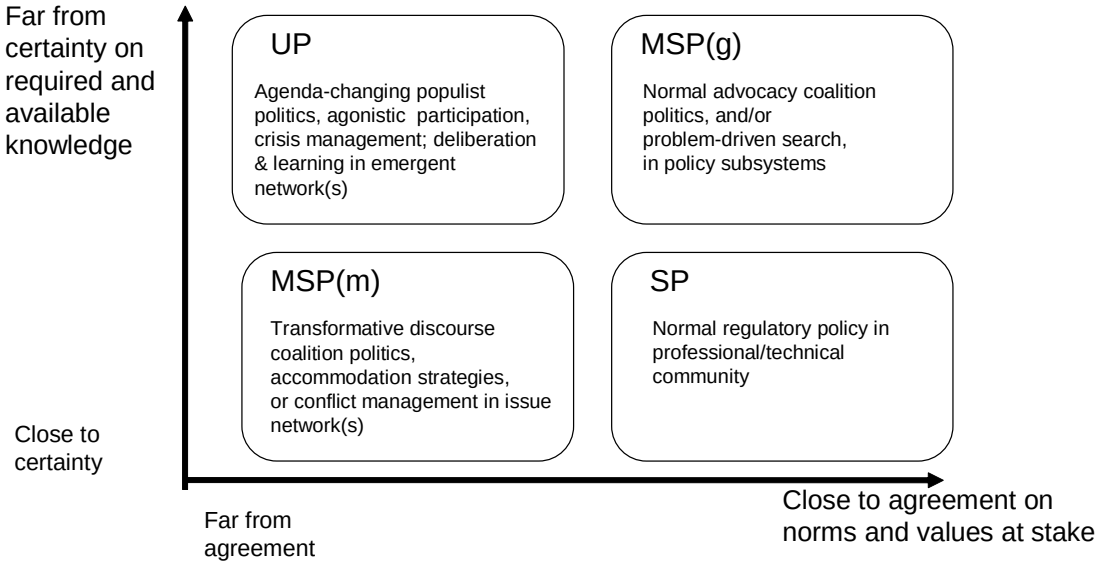

Figure 2. Problem structure typology and types of policy issue politics

Another influence depends on the *stage of the policymaking process*.[32] During the early stages of issue definition and agenda-setting, scientists have considerable freedom to deviate from the sacred notions of science-politics interaction. This offers them leverage to influence problem definition in public debate by scientific *narratives*, not necessarily only scientific *evidence.* In later stages of adoption/legislation and implementation, public scrutiny and formal role definitions of political actors (political parties, members of parliament, political executives) and administrative functionaries (government departments and officials) and media players (columnists, journalists, anchor(wo)men) force scientists to play by the strict rules of evidence-production and evidence-based policy. This means that the more a policy matures over time, the more the public status and role of science in policymaking becomes vulnerable to criticism and erosion.

The science-politics nexus is relatively easy to organise for (moderately) structured problems in the early phases of policymaking. In such cases, boundary organisations necessarily but willingly adapt to a politically dominant problem frame (hence the downward straight arrow from policy issue politics to boundary organisations in figure 1). In cases of conceptual use of science, usually in the early, plastic stage of agenda-setting for new policy problems, scientists (and boundary organisations) may strongly influence the problem framing itself[32] – hence the upward dotted arrow in Figure 1 from boundary organisations to policy issue politics. Importantly, political and cognitive tensions arise in the case of *wrong-problem problems*: when a policy problem is dealt with as if it is one type, while it should be dealt with as another. Most commonly, this occurs when policy problems once dealt with as structured, later in the policy process show re-emerging value dissent and lasting politically relevant uncertainties in the knowledge base.[30]

Political-cultural sphere

Boundary work is culture-specific. There is overwhelming evidence that responses to (new) policy developments are influenced by political cultures and regulatory styles.[33,34,35,36,37] The political-cultural sphere describes a particular governance space which coordinates the production, dissemination and acceptability of knowledges for political decisions. Normally political decisions have to align different types of knowledge from different actors: citizens, professionals, bureaucrats, and experts. The political-cultural sphere acquires its special character precisely because it implicitly or explicitly manifests a particular *public epistemology*, i.e. taken-for-granted expectations about the legitimacy and validity of these intertwined knowledges.[30,35,38] There is some evidence for the emergence of global or transnational cultures that influence national political cultures and policy styles.[39,40,41] Understanding the disjoint between these emerging global or transnational cultures, and particular local political cultures or civic epistemologies is crucial to understanding climate politics and boundary work in different contexts. As Hulme and Mahony[42] put it: 'Revealing the local and situated characteristics of climate change knowledge thus becomes central for understanding both the acceptance and resistance that is shown towards the knowledge claims of the IPCC' (Reference 42, p.714).

In the next sections this multi-level heuristic framework of boundary work, boundary organisations, policy issue politics and political-cultural spheres (Figure 1) will be used to discuss the most salient features of boundary organisations for climate change policy and politics in the international arena and in two selected industrialised Annex I political regimes (US and EU) and one industrialising or developing non-Annex I country (India). But first we discuss important empirical and conceptual limitations of this article.

Best practices?

When boundary work and boundary organisations are indispensible, the question about 'best practice' emerges. It can be evaluated in terms of politicisation of science and scientization of politics.[12] Both over-politicisation and over-scientization can be considered a failure of boundary work: they indicate that scientists and policymakers in their coordination efforts have ignored relevant demarcation issues. The evidence of dual participation, dual accountability and use of boundary objects can also be used to assess conditions under which creating credible, legitimate and salient knowledge for policymakers is likely to succeed.

Unfortunately, the question of best practice is easier asked than answered. First, there are still many 'blind spots', since the lens of boundary work has not been applied sufficiently often and in depth, certainly not in the study of (global or national) climate change science-policy interactions. In our review we found that existing literature focuses on a few Western countries and on the IPCC; and even there detailed descriptions of the inner workings of boundary arrangements are rare (see below). This means that the discovery of necessary and sufficient conditions in which criteria for 'quality boundary work' are met is near impossible since the detailed data needed do not (yet) exist. Second, even if data limitations were less serious, any criteria and conditions for 'good' boundary work can only be very broadly specified because successful boundary organisations have adjusted to their context of policy issue politics and political-cultural spheres. Moreover, boundary organisations not only work on the production of knowledge ('problem solving') within given problem framings that are separately settled at the policy politics level. Sometimes boundary work's impact on governance is greater when they advance and frame policy problems at this level, as will be illustrated by our analysis of IPCC. Whether or not such greater impact should be considered 'success' or a 'wrong-problem problem' is debatable, however.

MAKING CLIMATE CHANGE INTERNATIONALLY GOVERNABLE

International boundary organisations: a global climate change regime complex

Global climate change governance has entered the stage of a 'regime complex' due to its growing differentiation and apparent fragmentation[43] as a maturing policy domain in many subnational, national and transnational settings. This means that by now numerous institutions exist that mix scientific and political elements in remarkably different ways.[16] Key among the international boundary organisations are the rather well-researched Intergovernmental Panel on Climate Change (IPCC) which claims to coordinate the production of 'policy-relevant and yet policy-neutral' scientific work[42] and the far less researched Subsidiary Body for Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on Climate Change (UNFCCC).[15] SBSTA has been referred to as a 'gatekeeper' linking the predominantly scientific information provided by the IPCC to the policy-oriented needs of the Conference of the Parties (COP).[15,44] Related boundary organisations are the Climate Bureau, the Subsidiary Body for Implementation (SBI) and the Intergovernmental Negotiation Committee (INC, 1990-1995), the temporary body tasked by developing countries with steering the complicated international negotiations leading to the UNFCCC.[45] The latter three have hardly been researched at all.[46]

Collectively these international boundary organisations are embedded in and help constitute an emerging transnational multilevel governance culture[7] or a new global public epistemology.[36,38,47] Different from the relatively stable national public epistemologies, a fragile international knowledge order has to span a much wider diversity of scientific and political institutions from a huge number of countries and policy issue areas. This leads to confrontations between national epistemologies and boundary work arrangements.

The history of the foundation and early years of IPCC is such a clash between public epistemologies and policy styles; in this case between US climate scientists, the US federal government, and the UN. In the 1980s US climate scientists pressed for political and policy action from the US government based on their growing body of scientific knowledge and its dominant narrative of possibly risky global warming. US politicians reduced the domestic agenda setting power of US climate scientists to merely influence US climate research policy.[32] But the scientists kept advocating climate change policy action through bodies like the UN World Meteorological Organisation and UN Environment Programme. By allowing and encouraging the setting up a UN expert body, the IPCC, US politicians channelled climate change science activism in international policymaking channels. Although the US government embraced the same linear model of knowledge production and application as the climate scientists, it strategically used elements of the UN expert-bureaucratic culture that stresses representation over expertise and includes direct but fuzzy boundaries between scientific assessments and negotiation forums.[48] The intergovernmental character of the IPCC, including articulate arrangements for dual participation and accountability, meant that the US government could keep some political grip on the international activities of US scientists and influence the boundary work practices in the IPCC.

Even though IPCC was in practice a profane and back-office compromise between science and politics[45], it held on to a sacred and front-office narrative of a hegemonic US epistemic culture, that stresses strict rules and a sharp, but transparent science-policy boundary.[34] The furtive *de facto* co-production of a publicly espoused linear relation between climate change science and politics created an image of the IPCC as predominantly scientific. This image-building was more successful for Working group I (doing the climate assessments) than Working groups II and III (dealing with more mixed scientific and policy-analytic issues of mitigation and adaptation, respectively).

The flexibility of the division of labour between science and politics is especially clear in the boundary work performed in the SBSTA on the creation and maintenance of appropriate boundaries

and jurisdictions between interacting organisations.[15] The SBSTA delimited discussions between the IPCC and the COP based on whether particular issues were considered political or value-based decisions (best dealt with by the COP) and scientific issues (best dealt with by the IPCC). Such inter-organisational orchestration is not limited to the SBSTA however[23,22,45]; for example Fogel[49] illustrates the complex mix of 'puzzling and powering' that occurs in both the SBSTA and the IPCC around issues such as defining the terms of reference of an IPCC special report (which occurred at the SBSTA), to struggles around the precise distinction between policy relevance and policy prescriptiveness (which occurred in the IPCC), to debates and struggles about the presentation and management of uncertainty (which occurred in the IPCC).

Framing the climate change problem as global warming

In the 1980s until the 1992 adoption of the UNFCCC, international boundary work has had a major impact on how climate change was structured and framed as a global, world-wide issue. Framing climate change as a global policy issue settled the boundary arrangements for the co-production of climate change science and climate change politics until the 2009 events of 'climategate'. In addition to the politics of issue recognition and mobilizing political support, crucial cognitive steps were taken to structure and frame the three elements that shape any public policy problem: problem ownership, causality, and accountability.[50,51]

An all-important element of framing a policy problem is to fix its *causality*. In line with scientific consensus on the narrative of a global climate crisis scenario as global warming, and scientific practices of using Global Circulation Model simulations, climate change was politically defined as a *global* issue.[52,5354] This 'globalisation of the atmosphere'[52] came to side-line previously dominant discourses that had framed increasing atmospheric carbon dioxide in terms of specific risks to local places. It also settled the *ownership* of the problem: As Miller puts it: '[o]nly when the Earth's climate was re-imagined as a global system, bringing views of the atmosphere into line with assumptions about the jurisdiction of international institutions, did claims about climate change begin to engage with debates about international politics'(Reference 52, p. 51). Formally, problem ownership was settled with the adoption of UNFCCC in 1992. This meant that the issue was to be tackled through the institutional architecture and features typical for international multilateral agreements. UNFCCC and the Kyoto Protocol were constructed by analogies from past treaties.[45,55] The designers thought the global warming problem ought to be tackled through global emission controls, 'treating tonnes of carbon dioxide like stockpiles of nuclear weapons to be reduced by mutually agreed and verifiable targets and timetables'.[56] Once problem ownership was politically settled, *accountability* disputes immediately sprang up. The global scale of the climate change problem results in a notable asymmetry experienced by local populations who are asked to meet locally concentrated short-term costs (around which there is little uncertainty), in order to reap globally dispersed future gains (around which there is considerable uncertainty).

This unresolved issue of scale and time asymmetry inevitably involves both intellectual and political struggles on how to draw boundaries around problems.[7] From a political 'powering' angle, policy framings that locally concentrate certain costs to achieve globally dispersed long-term and uncertain benefits require an actively persuasive style of politics and policy implementation.[57] This framing impacted in two ways on national decision making climates. One is the political polarization between activists and 'wait-and-see' defenders, as in the US pluralist system, exemplified by both fierce protagonists like Al Gore, and committed antagonists like the 'braking coalition'.[45] The other impact is dramaturgical or symbolic politics[58] manifest in EU and European countries' politics. It means grand-standing during COPs on (supra)national carbon dioxide stabilization or reduction targets, in full knowledge that these public promises are unachievable in the normal channels of slow and step-by-step policymaking back home.

These different styles of policy issue politics lead to remarkable differences in boundary work. Both activists and symbolic incrementalists will be inclined to invite and believe science to reduce knowledge uncertainty. Antagonists or 'deniers', in turn, will scrutinize the science for errors and uncertainties, thereby creating boundary organisations as 'merchants of doubt'.[59] But even for the cognitive 'puzzling' by incorruptible scientists issues of scale and time asymmetry lead to serious disputes over uncertainty management. On the one hand, conscientious scientists dutifully communicate uncertainty in their findings. On the other hand, they are aware of the possible strategic uses of scientific uncertainty in politics.[45] Thus, scientists convinced about the truthfulness of their own research and of the need for politicians to take action, will be tempted to deliver the certainty politicians desire. This may lead to boundary work as 'stealth advocacy'.[55] Looking at the stepwise increased certainty of IPCC statements about the probability of the anthropogenic part of global warming, and the way the EU and EU countries have used the IPCC as an 'uncertainty reduction machine' to close down national climate change policy debate and uphold the Kyoto negotiation process, it is only understandable that both political actors and scientists have question marks about the role of IPCC and European boundary organisations. It demonstrates the tendency of boundary organisations to become vulnerable to losses of credibility and trust as 'their' policy issue matures, but with less than promised tangible results.

In addition, and perhaps even more important, accountability struggles around the global framing of the climate problem drive a wedge between rich and poor countries. Thus many developing countries resisted the global, technical framing of the climate issue, based on climate modelling in North America, Europe and Japan, arguing that issues of development, equity and poverty alleviation were fundamental, and should not be brushed aside in the new climate regime.[60] For example Biermann[61] focuses on the IPCC's decision to divide emissions into just two categories (natural and anthropogenic) in its first report in 1995, rather than making a distinction between subsistence emissions (such as those resulting from rice farming and livestock) and more luxury emissions (such as those resulting from car transport). He suggests this correlated with the overwhelming participation of northern scientists.

In light of the widespread awareness of the regional bias in participation at the IPCC, several mechanisms have been suggested to increase participation by developing country experts in international boundary work, notably by funding travel costs to meetings, and calls for increased funding for the development of climate models in southern institutions. However, none of these suggestions would alleviate the deeper discursive dominance of particular issue framings policy.[62,63,64] As Friman and Linnér[60] put it: '[s]chooling people in the workings of a closed discourse – that is a predefined way of framing an issue – is not the same as promoting an inclusive process' (Reference 60, p. 347).

They argue that regional biases in the framing of climate change result from dominant disciplinary framings of the climate issue, particularly a 'non-inclusive biophysical discourse traditionally preferred by Northern policy makers' (Reference 60, p. 339; see also[65,66,67,68]) There is growing recognition of an 'epistemological hierarchy'[67] in the regime of climate governance, whereby certain types of knowledge, most notably the geophysical sciences, and economics, are promoted while others are marginalised.[69] O'Neill et al argue that this bias matters because '[b]y marginalizing certain framings of climate change — framings which may help to address the "wickedness" of climate change — fruitful political and social responses may be excluded' (Reference 67, p. 998).

In the section on non-Annex I countries like India we return to these issues. All in all, when the scientific causal narrative of atmospheric warming inspired a political problem definition as global warming[70], political questions of problem ownership and accountability or responsibility were practically immediately given. The scientific-cum-political consensus of the early days of global climate change policy 'froze' into an international policy infrastructure which included boundary

organisations like IPCC, SBSTA and the UNFCCC as major players. Since climate change was considered a (moderately) structured policy problem with considerable goal consensus, western politicians and climate scientists alike found it easy to set up and legitimise boundary organisations and boundary work as one-way communication and cooperation: climate science informs climate change policy which will solve climate change problems. Publicly espousing this sacred narrative obliged players from both institutional spheres to downplay the every-day realties of their collaboration. Thus, the day-to-day management of boundary organisations as hybrids between politics and climate science was forced to keep the official and public right hand from knowing what the informal and off-the-record left hand was simultaneously doing. This formally upheld image of international climate change boundary organisations was to legitimise climate change discourse and especially the UNFCCC approach the climate change policy for decades to come.

NATIONAL AND REGIONAL RESPONSES

This global problem framing and the global governance regime did not transfer unchanged or unchallenged to national levels. Rather, boundary work and boundary organisations at national level display strong instrumental roles in support of their national governments. We illustrate this through a brief sketch of boundary work and boundary organisations in the US, the EU and India. We selected these examples as demonstration of the range of international responses: the US as industrialised country resisting the UNFCCC's Kyoto regime; the EU as strong supporter; and India as a leading developing country in opposition. Another reason for selecting the US and the EU is that boundary organisations and their contexts have been studied to some extent. We opted for India as one of the largest two of the emerging economies with most political influence, China being the other one, who also have the largest future carbon dioxide emission potential. Here we had to rely on literature that describes climate change governance in general, since boundary work concepts have not been used to analyze the arrangements in India.

Boundary work in the US and the EU: politics on top, science on tap

While the contents and conduct of policy debates in climate change are different in the US and the EU, they share two important similarities: the global and biophysical character of the climate change problem, and the strong focus on mitigation as a solution. This premature closure of the policy issue framing called into being very different but instrumental roles for science, and limited opportunities for re-framing. The different manners of this instrumentalisation of science, especially regarding the function of boundary organisations, is largely determined by the different public epistemologies.

Boundary work in the United States: the US as 'laggard'?

The United States has resisted binding international emissions targets or federal-level emissions controls; preferring instead to focus on voluntary programs.[71] Ironically, given their image as a 'laggard' in global climate policy, federal funding for climate science is the largest in the world.[24] Key among climate-relevant boundary organisations is the US Global Change Research Program (USGCRP) which coordinates and integrates approximately 2.6 billion dollars of research, and is responsible for coordinating US participation in the assessments of the IPCC. US scientists thus keep playing an important role in the IPCC, but they do less so in national US climate change politics and policy because their domestic influence is *de facto* limited to *climate change research policy* only.[32,72]

Boundary work for *climate policy* itself takes place in the very visible shadow of political power. The body whose task it is to integrate, evaluate, and interpret the findings of the USGCRP for policy makers, and develop an assessment of global change impacts and adaptation and mitigation strategies for the US, is the program of National Climate Assessments (NCA).[35] On a day-to-day basis, the President's Council of Advisors on Science and Technology (PCAST) plays an important role at the boundary between science and national policy-making. In line with general policy on issues of

science, technology and innovation, laid down in the Federal Act on Advisory Committees (FACA), all federal advisory committees (including NCA and PCAST) are (largely) held in public and reports from the meetings are made public. This builds on an important aspect of the public epistemology of the US where conducting deliberations under the public gaze is considered 'the best way to wash out personal bias and subjectivity' (Reference 35, p. 269). However, this increases credibility problems for boundary workers when even small parts of back-office coordination aimed at reconciling political and scientific criteria for good policy become publicly accessible, for example through media research and commentaries.

Another reason for the lower likelihood of a national consensus on policy problem framing is the pluralist nature of the US federal political system, which is characterised by public dispute and controversy. A striking feature of the climate change debate is its politicization (largely along Republican/Democrat lines). There exists a powerful, vocal (and largely Republican) climate sceptic lobby, whose views can be summed up in the words of senator Jim Inhofe (R), who stated that 'man-made global warming' was the 'greatest hoax ever perpetrated on the American people'.[17] The US climate science system, like the political system, is pluralistic, consisting of competing research institutions funded by different federal agencies and non-governmental interest groups, each with its own approach to climate science.[73] This largely accords with Jasanoff's description of the pluralistic nature of knowledge making practices in the US public epistemology where each party, provided it has money to pay for it, commissions its own research-as-argument, resulting in an apparent lack of research impact on the overall policy outcome.[35]

While some observers argue that the prevalence of industry-sponsored climate scepticism in the US is responsible for its lack of support for global climate governance, or for the lack of federal level climate policy[59], others argue that the presence of climate sceptics in the US is not the *cause* of the problem but a *symptom* of the way in which climate science has become inter-twined with a single, top-down international policy framework.[74] Such a governance regime generally does not sit well with the institutionally reinforced US preference for more disjointed and fragmented policymaking that incrementally learns about best practice. This is one important reason why the US has initiated and supported 'mini-lateral' climate policy initiatives outside the remit of the UNFCCC and the Kyoto Protocol. In terms of boundary work, this implies a preference for temporary, ad-hoc and tailor-made boundary arrangements over well-established and funded boundary organisations at national scale. Here is a major difference with boundary work in the EU.

Boundary work in the European Union: 'leader' in international climate politics?

The EU has always cast itself as a supporter and diplomatic leader of an international climate policy regime. However, the EU role was not devoid of self-interest.[39] Internally, the EU was looking to environmental issues as a new legitimation of its very existence; externally, climate change being perceived as the world's greatest sustainability challenge, claiming a leadership role provided the EU with an opportunity to showcase its political identity to its own member states and their citizens (UK secretary of state Miliband in 2006, quoted in Reference 55, p. 106). Setting up itself as 'leader' over and against the US as 'laggard' helped boost the EU's weight in the global political arena.[75]

In contrast to the highly politicized US political system, the EU is a governance system specializing in de-politicized regulatory policy, whose primary need is scientific advice.[76] EU climate change policy is largely made by the European Commission's bureaucracy in Brussels, especially the Directorates-General for Environment and Research, even though its major boundary organisation, the European Environmental Agency (EEA) is located in Copenhagen. Originally cast in the narrow role of independent information provider for policymakers and the general public, the EEA contributed to the early formulation of EU GHG stabilization targets and timetables. EEA is also credited by some authors for some less instrumental and more conceptual contributions to climate change policy through the design of market-driven policy instruments, the precautionary principle (its study *Late*

Lessons from Early Warnings, 2001) and methods and procedures for iterative risk assessment.[77] The advocacy by EEA experts for market-based policy instruments was at first resisted by DG Environment because EEA's mandate did not include policy design and evaluation.[78] Since these functions were added in 1999, EEA developed into a full-fledged boundary organisation.[24] As well as the EEA, several units of the Joint Research Centre perform boundary work functions for the Commission *de facto* as quasi-independent extensions of the EU bureaucracy.

The European Commission cherishes its boundary arrangements not only as resources for advice, but also as vehicles for political articulation of research questions and steering of knowledge production. Its European Research Area (ERA) initiative and the Framework multi-year research programmes are all strongly geared to the EU's knowledge demand. Using these instruments, the EU effectively creates boundary projects and ad-hoc arrangements that unite and coordinate research activities of major European knowledge institutes and universities. Swart et al.[79] report on the myriad boundary projects in European countries working on issues of climate adaptation. This ties the scientists involved to instrumental contributions to existing EU-level policy lines; where they try to go for more conceptual and critical contributions, these are frequently nipped in the bud.[78,80]

Jordan et al. [81]clearly show how policy instrument design (for environmental policies) is strongly influenced by national policy styles and cultures, and is not the technical, apolitical process that the label 'policy instrument' suggests. For example, EEA experts' choice for market-driven, as opposed to tax-based, climate change policy instruments was as much a political choice to respect taxation as the hallmark of member states' sovereignty as it was a technical-instrumental contribution to climate change policy. In a prophetic article, Wynne[82] described the EU's emerging climate change policy as 'early warning' for the importance of political culture in policy design and implementation. He predicted for example how differences between economic sectors and countries, especially between the North (Denmark, The Netherlands, Germany) and the South of Europe (Italy, Spain, Greece), would cause deep and lasting disagreements on binding carbon reduction targets due to different carbon intensities. For scientific expertise this has meant that EU expert bodies like the EEA and especially national environmental expert bodies have been exposed to, on the one hand, trends of harmonization and expert consensus for the sake of creating a single European market, and, on the other hand, expert pluralisation for the sake of decision support to regional and national climate policy initiatives.[83]

Boundary work in India: domesticating climate change as foreign policy

The overall response to international climate change science-policy developments in prominent non-Annex I countries such as India and China is a rejection of the dominant problem frame and solution strategy. With their increasing economic and political power, this negative response to and interaction with the global climate regime is increasingly important. However, little is known about the boundary work that occurs in these countries. Climate change was initially only on the agenda in these countries because of UNFCCC negotiations and was therefore, and still remains, mainly a foreign affairs issue. The perceived need to respond to such external policy initiatives has often driven analysts' efforts to develop a national perspective and to build linkages with domestic policy-makers.[84,85] So far, international policy such as the Clean Development Mechanism (CDM) is mainly used to help solve domestic problems.[86]

In India, energy is seen as the key to economic development and this is a main cause for unwillingness to take on emission reduction commitments. Hence, the international framing of climate change policy as mitigation hindered explicit national climate change policy-making, even though policies were developed that contributed to the same goal. Some initiatives were taken in relation to the energy and forestry sector which are to a large extent compatible with the requirements of international climate change policy but are not framed as such.[87] Vulnerability to climate change is an emerging issue and this could contribute to elevating the climate change issue

on domestic agendas in the future. However, recently the Indian government has tried to reframe prevailing political discourses on climate change by introducing new frames and storylines that emphasize climate change as a national concern rather than as an international matter.[88]

India (like other non-Annex 1 countries) has long argued that responsibility for climate change historically resides with the developed world. International emissions caps are viewed as 'deepening the north–south divide' by capping emissions just as its development is taking off.[89] In India there is a strong perception that the international negotiation processes are a disguise for continued economic and political domination of developing countries by the industrialized North[90]; getting into substantive discussions may only weaken the position of the country.[87] Finally, foreign funding for climate change policy analyses is dominant. Multilateral and bilateral agencies attempt to impose their own (dominant) views of these countries' role in 'global' policy for climate change, so policy analysis is biased towards mitigation rather than the more relevant assessment of vulnerability and adaptation strategies.[84]

India has a relatively stable democratic political system, a relatively well informed governing class, a free press, a well-established scientific community and active nongovernmental organisations that should be, in theory, well-placed to support, promote and demand quality climate change-related policies. However, freedom of information has been an issue. Until 2005 access to governmental documents and technical reports were available, if at all, only through leaks or other informal channels[91]. In 2005, the Right to Information Act was introduced and climate activists and researchers have used it to get access to government documents.[92] Mistrust in scientific institutions and a lack of regional knowledge may adversely affect both mitigation and adaptation efforts.[88] Foreign funding helps keep issues on the donor agencies' agenda alive in Indian science and policy circles.[93]

Modelled on the British system, links between scientists and policy makers often operate in an informal manner. Generally, India's 'policy for science' has been dictated by close alliances between powerful leaders and their scientific advisors. Prior to IPCC or UNFCCC meetings these experts might be called upon to provide rapid advice on a particular issue, as and when needed, produce position papers upon request, and to participate in more structured activities to inform and guide policy-makers prior to UNFCCC or IPCC meetings. Many of these advisors are over-subscribed and play multiple roles: as scientists and analysts, as advisors to the Indian government, and as members of the IPCC or other international bodies. Although this places limits on the time that the top cadre of experts can devote to active research, it also allows them to gain a comprehensive view of issues surrounding climate change, and to develop a well-informed stance. As far as national policymaking is concerned, there is substantial turnover in the personnel handling any particular issue in the government. Consequently, the Ministry of Environment and Forests lacks a systematic approach for dealing with climate change, and there are almost no mechanisms for building in 'institutional memory' on the issue. This has led to frustration among many in the research community about the lack of interest in climate change issues at the national policy level.[84] Kandlikar & Sagar's 1999 assessment[84] was confirmed by the 2010 Climate Revolution Initiative report.[92]

Policy analyses of the social, economic, and technological aspects of climate change are primarily conducted at a few large NGOs, research institutes, and some academic institutions. The Tata Energy Research Institute (TERI), a think tank in Delhi, and the Center for Science and Environment (CSE), a Delhi-based NGO, are the two most prominent players. They have been involved since the inception of climate policy and offer a traditional understanding of policy engagement through proximity to government actors and involvement in policy networks.[94] The timing and targets of their efforts are often chosen strategically to make an impact upon the Indian policy stance. TERI is a mainstream organisation whose advice is important to the government. CSE emerged as one of the most articulate and influential environmental voices in India and appears to enjoy almost a symbiotic

relationship with the Ministry of Environment and Forests (MoEF). It was CSE who in their 'citizens' report'[95] challenged the assumptions behind the calculations in a 1990 report of the World Resources Institute (WRI) which stated that developing countries ranked high among greenhouse gas emitters because of deforestation and other human activities resulting in carbon releases, thus showing the importance of scrutinising 'Western' science. To aid information flows and enhance the credibility of national climate policies the Indian government has recently instituted the Indian Network on Climate Change with involvement of various scientific bodies around the country, the Mission for Strategic Knowledge as part of the NAPCC, and the Low Carbon Expert Group comprised of representatives from government, industry and civil society.[88] It is too early to assess what impact these organisations have.

The overall picture of science-policy interaction in India is (a) general lack of scientific capacity to provide knowledge needed for policy-making, and (b) bias towards producing science for international negotiations. Globally, the majority of the climate analysts are from industrialized countries and their work has generally focused on issues directly relevant to these countries. Members of the Indian research community are acutely aware of this ideological divide, and more specifically, of the political nature of the international assessment process. They recognize not just the South-North divide on climate change emissions and responsibility, but also in the inequities in the assessment capability, as well as the broader international context (such as economic globalization) in which the climate change issue sits. Their concerns vis-a-vis climate research and assessment include inequities in participation and decision-making about agendas, in funding, in research infrastructure, and in the representation of, and barriers to the acceptance of, ideas.[88]

CONCLUSION: LOST IN THE PROBLEM

Global boundary work: clinging to climate change as (moderately) structured problem

Summarising global climate change governance from a boundary work perspective we conclude the following. First, at the level of global policy issue politics, the IPCC was set up in the early stage of issue definition and agenda-setting as a boundary organisation that assumed climate change was a technical issue, downplaying fundamental disagreements on goals and deep uncertainty on facts and means, and choosing the corresponding linear approach to science-policy interaction.[55,96] In other words, in the implicit policy issue framing used by UNFCCC global climate change was a structured problem, when in fact, certainly in the international policy arena with many non-Western countries involved, climate change was and still is a paradigmatically 'wicked' or unstructured problem where knowledge is uncertain and societies disagree on norms, values and goals.[53] In such circumstances boundary work ought to have been more about opening up than closing down policy debates.[64] By focusing on a single policy framework inspired by previous structured problems like nuclear arms reduction and ozone depletion, the UNFCCC-Kyoto protocol, the political space for debate was effectively closed down. Hence, Sarewitz[74] plausibly argues that support for global climate policy has become indistinguishable from support for climate science, and political opposition to the UNFCCC is expressed as distrust of the science. In 'climategate' and the events in its wake this science-oriented boundary management of science-policy interaction exposed itself to serious allegations of inept management-by-hypocrisy.[97]

Consistent with their assumption of a structured policy issue, the IPCC aimed for technical-specialist advice that would be instrumental, serviceable and solution-oriented for regulating 'one' global warming problem, to be tackled in a 'sound science' informed, harmonized, and standardized way for, in the end, all countries of the UN. Since its early beginnings in the 1980s, the UNFCCC policy community has doggedly clung to this approach. Ambivalent about its character as a true boundary

organisation, IPCC never developed its potential for co-production between science and politics to the full.[23] As observed by Siebenhüner[44], the IPCC missed opportunities for learning. He noticed only first-order, instrumental learning in the IPCC and UNFCCC. No second-order reflexive learning took place, i.e. consideration of changes in the prevalent knowledge system, reinterpretation of purposes, choice of policy instruments or governance strategies. Haas[31] similarly judges that, although the early IPCC may have been successful in international agenda setting and in upholding credibility in climate knowledge, its legitimacy (for the US and developing countries) and salience (for all countries) were actually rather low: 'the IPCC is designed to keep science on a tight leash by controlling the selection and autonomy of individual scientists engaged in the assessment process. Consequently, the degree of usable knowledge generated by the IPCC has been limited.[44] In the debate on the role of the IPCC following 'climategate', the InterAcademy Council was charged with reviewing the IPCC's procedures. In this review the boundary organisation character of the IPCC was not given due attention. Instead, the InterAcademy Council concentrated on scientific credibility issues by sharpening up the review procedure; less attention was given to legitimacy and salience issues, or more generally to the role assigned to the IPCC in the international and national climate policy regimes, although these issues are at least as significant for the status of the IPCC and the knowledge it produces.

From such perspectives, 'climategate' was waiting to happen, as anticipated by Demeritt in 2001.[54] Instead of being designed as 'certification machine' and 'scientific trigger' to depoliticize a multilateral international agreement and further 'smooth' implementation, the IPCC should have been designed as a conceptual, critical and problem-oriented scientific and stakeholder forum for discussing and preparing strategic advice through opening up political debates and demonstrating the 'serviceability' of more than one type of policy discourse. The few studies of SBSTA show that it was more successful at this at the time than the IPCC, albeit much slower to produce agreement.[15]

Second, at the level of political-cultural spheres, climate change was from the start framed as a global issue for which global solutions had to be found.[52] However, although the IPCC claims to present universal, 'policy relevant but policy neutral' science, this science is not universally accepted as valid and authoritative or neutral. Jasanoff[36,98] explains this as a problem of 'global public epistemology': 'Though 'intergovernmental' in name, the IPCC is not answerable to particular national traditions of policy legitimation… Claims about the environment and its sustainability produced by such novel bodies inevitably function as sites of contestation among competing models of knowledge-making and governance' (Reference 98, p.240). As global climate policy-making matured, national boundary arrangements, issue politics and political-cultural spheres responded differentially to the 'universal' climate change science. The geographic bias towards participation by experts from developed countries in IPCC assessments only meant that the issues raised by the global South were marginalised or ignored.[87,99] Indeed, 'global environmental policy making [..] needs to take serious account of deep-seated national ways of knowing and acting, in short of civic epistemologies' (Reference 36, p.140).

Third, global boundary work failed through both over-politicization and over-scientization. Both Demeritt[54] and Sarewitz[74] argue that politics seeped into climate science at the international level because of the global framing and the association of climate science with just one policy option, i.e. the Kyoto Protocol. The other problem, the scientization of politics or the 'rendering technical'[100] of climate change also appears to be widespread. For example Friman and Linnér[60] show how equity issues were transformed and obscured by technological debates and discussion at the IPCC, when 'the historical responsibility issue became stranded on problems of how to correctly represent physical nature in climate models' (Reference 60, p. 339). Quality boundary work would draw more on politics to deal with value issues and more on science to deal with knowledge issues, while organising and managing the interweaving of both.

In the long run this situation in no small measure contributed to the challenges IPCC faced in the events of 'climategate' and subsequent exposure of mistakes in the Fourth Assessment Report. In the snake pit of global warming politics, global boundary work required careful oscillation between sacred/profane and front/back-office accounts of the IPCC's international activities. The IPCC was under ever more scientific and political scrutiny due to its ever stronger statements on the certainty of the anthropogenic part of climate change in its successive assessment reports. Yet it was unable to be transparent to politics and science at the same time because the taboos in their sacred narratives. Hence, the IPCC's boundary work became gradually more and more entangled in what Brunsson[97] aptly called 'management by hypocrisy'. When the deliberate or inadvertent leaking of email exchanges between leading climate scientists suggested manipulation of the peer review process[55], the IPCC's reputation for credibility went into a downward spiral in western countries, while its legitimacy problems within developing countries were only confirmed. Direct repair work on credibility by the IAC leading to minor adjustments in IPCC protocols proved to be 'too little, too late'. In COP15 at Copenhagen the entire UNFCCC/Kyoto process came to a standstill; in later COPs the aspirations of the failed Kyoto process are toned down considerably.[101]

Learning from national boundary arrangements?

In all country studies the instrumental nature of boundary arrangements, organisations and projects stands out, serving the political interests of states (in the EU and in India) or the political deadlock within a country (in the US). This affirms that having 'our experts' is crucial in national and international boundary work. Boundary work theory implies that expertise is a social relationship between a provider and user of expertise. Therefore, 'nationalized' expertise provides higher trust (closer sources are more credible) and political control (closer link between science and national politics).[80] The US efforts to 'inter-governmentalize' the IPCC were inspired by the same logic.

In developing countries like India boundary work is less structured than in the developed world. Boundary work for climate issues occurs mainly in informal, personal contacts between politicians, policymakers and scientists, sometimes working in state-supported think tanks, although boundary arrangements have recently been set up. However, after initial resistance to the climate change issue as another vehicle for continuing western dominance in a globalizing economic world order, the issue is somewhat gaining in legitimacy and salience mainly through embedding in other related national policy issues such as energy.

In the EU we observed centrally harmonized and coordinated, instrumentalized boundary work arrangements and projects. Very different from the US, the EU uses its quasi-independent and decentrally located boundary organisations as vehicles for demand articulation and steering of climate change knowledge. In addition to the institutional self-interest in supporting a unitary and top-down international climate regime, this makes for very instrumental boundary work that would not seriously challenge problem definitions and belief systems at global or national levels.

In the US, a pluralist political structure and adversarial culture leads to a polarized and politicized set of boundary arrangements, external to government, and with a sharp boundary between science and politics (at least in front office discourse), although most climate science is government-sponsored. Fragmented, disjointed and experimental policymaking processes have created a contradiction between federal government as sceptical, and many state and regional and municipal governments as supportive of climate change policy. Local extreme weather conditions like hurricanes Katrina and Sandy may have contributed to (sub-)state level willingness to initiate and implement adaptation projects. Therefore, interestingly, the situation in the US has created contradictory tendencies in climate change politics that have frequently led to a 'dialogue of the deaf', but have at least the potential of opening up public and policy debate.

While some authors have focused on examining potential ways in which key boundary organisations such as the IPCC could improve their effectiveness, like the 'earth system governance' project[102], others see increasing fragmentation of the climate regime, the uncertain and variable policy status of climate change knowledge, and the apparent failure of policy to achieve meaningful emissions reductions, as evidence of a fundamental flaw in current global framings of the climate change issue.[103,104] They suggest that the inability of COPs since 2009 to reach any meaningful agreement on emissions reductions, signals the end of the era of global top-down policy instruments such as Kyoto, and perhaps the start of a new approach to the global issue of climate change including more diverse measures[56] or a return to 'mini-lateralism'.[93] In a related vein, others draw hopeful attention to the growing divide between what is actually happening in the world in terms of diverse policy-making initiatives, and the global climate policy talks.[105] Whatever the case, it should be clear that successful boundary arrangements are those that have adjusted to their diverse national contexts of policy issue politics and political-cultural spheres. Endeavours to identify imitable 'best practice models' for boundary arrangements in some detail soon run into these limitations.

Ways forward: opening up debate

What, then, can be done at this point? Acknowledging the climate change issue as unstructured policy problem, boundary work should aim to provide pluralized strategic advice, conceptual clarification, and critical deconstruction of issues of uncertainty and normativity (see Figure 2). It should be more problem- than solution-oriented in debates, and influence different agendas in different parts of the world. The international boundary organisations should move from being geared to a centralized, rational rule approach to a much more disjointed, geographically differentiated innovative policy processes. This means "innovation" in the double sense of "governance of innovation" (e.g. of energy decarbonisation) but also "innovation of governance" (away from outdated, inflexible UN multilateral agreement strategies)[106]. It can be argued that this differentiation is already occurring[101,107], in which case the pertinent questions are how to sensibly link the different elements of the multi-actor and multi-level climate governance regime, and if any, what the role of the UNFCCC could be in this regard.[101]

Opening up policy debate requires fostering of multiple scientific theories on climate change. Politicians should no longer cast global science in the role of certification machine, but develop their own local or national policy framings, responding to climate change in their own terms and ensuring boundary arrangements are fit for this purpose. It seems also obvious that global climate governance must draw on a much broader range of knowledge and stakeholders.[108] For IPCC the radical implication may be its transformation, except for the scientific assessment tasks of Working Group I. Instead, it should be reformed as a global "UN Centre for Climate Change" for study of potential approaches and instruments for climate policy-making, engaging in reasoned debate on problem structuring and alternative ways of problem decomposition, and establishing and developing 'situated' branches that support national, regional, local and manifold transnational policy initiatives through a portfolio of approaches and strategies of democratic governance where there is space for ignorance and surprise.[109]

Apart from practical reforms, there is good reason for more empirical research using the boundary work lens for lesson learning. The intensive boundary work at SBSTA, SBI and (in 1990-1995) INC, has hardly been studied. Yet it is imperative for climate policy to gain more knowledge of policy-analytic boundary work for instrument design in multi-stakeholder and high-stakes settings.[108,110] Equally, little is known about how boundary work actually happens, even in countries like Germany or the UK, let alone in developing countries. Given the international and transnational character of collective action on the climate change issue, a return to subnational and national incremental governance approaches is not desirable. We need a truly multi-level approach to the study of governance regimes. It is imperative to closely study and learn from global-local boundary work

dynamics[40] and study if and how lower-level incremental approaches trigger policymaking responses in other countries or levels of governance.[111]

Lesson drawing and best practice research, however, have their limits also when it comes to boundary work. This is partly because they do not travel easily from one context of application to another: boundary work experience with ozone depletion, nuclear radiation and acid rain turned out to be not very usable for climate change. More importantly, our inability to know enough forces us at some point to stop the cognitive process and shift to action. Hence, any learning in a political task field should not be limited to scientific research and lessons based on analysis; it necessarily takes the shape of pragmatic trial-and-error learning by variation-and-selection. We hope that this analysis of boundary organisation and boundary work for climate change knowledge and politics becomes part of a larger learning process for renewed efforts to create and maintain a productive and creative tension between science-as-puzzling and politics-as-powering in the struggle over policy.

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